PRODUCTION OF A CONNECTING ROD OF AN 8HP DIESEL ENGINE BY REVERSE ENGINEERING TECHNIQUE USING LOST WAX CASTING METHOD

P. E. Amiolemhen[1*], F. C. Nwosa[1]

[1]Department of Production Engineering, Faculty of Engineering, University of Benin, PMB 1154, Benin City, Nigeria.

ABSTRACT

The aim of this work is to produce by reverse engineering method, the connecting rod of a single-cylinder, four-stroke, 8-hp diesel engine using lost wax casting and machining processes. The connecting rod to be produced was sourced from an 8hp diesel engine generator. The dimensions of the connecting rod were taken and recorded and a hand sketch of the connecting rod was made. An engineering drawing was produced from the connecting rod sketch that was made. A pattern made of wax was produced from a pattern-mould box made of ceramics. The mould that was used to cast the connecting rod was made of green sand. A replica the an 8hp diesel engine connecting rod has been produced by lot wax casting using reverse engineering method. The values obtained for engine speeds and engine temperatures for the control engine and the engine with the manufactured connecting rod were very close under the two experimental conditions, which confirmed that the efficiency of the manufactured connecting rod is close to that of the original connecting rod.

KEYWORDS: Reversed engineering; lost wax casting method; connecting rod; connecting rod cap, Internal combustion, engine speed

1.0 INTRODUCTION

The major problem bedeviling the Nigerian manufacturing sector is the dearth of technology, which is as result of the advanced nations not willing to transfer technological know-how to developing nations like Nigeria. This challenged has been taken up by some indigenous researchers on the need to locally develop the manufacturing sector by first developing the technological know-how through reverse engineering technique (or copy creativity). Copy creativity of this kind requires a good knowledge of manufacturing processes, ingenuity, patience and a strong will to succeed (Ibhadode, 2008).

The internal combustion (IC) engine consists of many different components and parts that are assembled together to perform its intended function. The connecting rod is a major link inside of a combustion engine. It connects the piston to the crankshaft and is responsible for

Corresponding author. Email: patrick.amiolemhen@uniben.edu

transferring power from the piston to the crankshaft and sending it to the transmission. The connecting rod is the most common cause of catastrophic engine failure. It is under an enormous amount of load pressure and is often the recipient of special care to ensure that it does not fail prematurely.

A lot of contributions have been made to the definition of reverse engineering by different researchers Manzoor et al, 2008; Abdullahi and Umar (2006); Ibhadode, 2001; Ebhojiaye and Ibhadode, 2013).

There are different types of materials and production methods used in the creation of connecting rods. The most common types of connecting rods materials are steel and aluminum and the most common type of manufacturing processes are casting. In lost wax casting, mould-maker creates an original pattern from wax (Ravi, 2003).

This research study is concerned with the production (by lost wax casting method) of connecting rod of an 8hp internal combustion (IC) engine by reverse engineering method.

2.0 METHODOLOGY

2.1 Design and materials selection

This research study is centered on the development of local manufacturing sector by the use of locally sourced materials, labour, skills and tools to carry out a reverse engineering production of the connecting rod of an internal combustion engine.

Material used for the production of the connecting rod is cast iron, while bronze was used to produce the journal bearing that was force-fitted into the connecting rod end that the piston rod will go through with mild steel connecting rod bolts.

2.2 Development of connecting rod pattern

The sample of the connecting rod shown in Figure 1 was sourced from an 8Hp diesel. The wax pattern was formed to shape by ceramic mould constructed from the dimensions obtained from the engineering drawing of the sample-connecting rod as shown in Figure 2.

Figure 1: Sample-Connecting Rod Sourced from the 8hp Diesel Engine

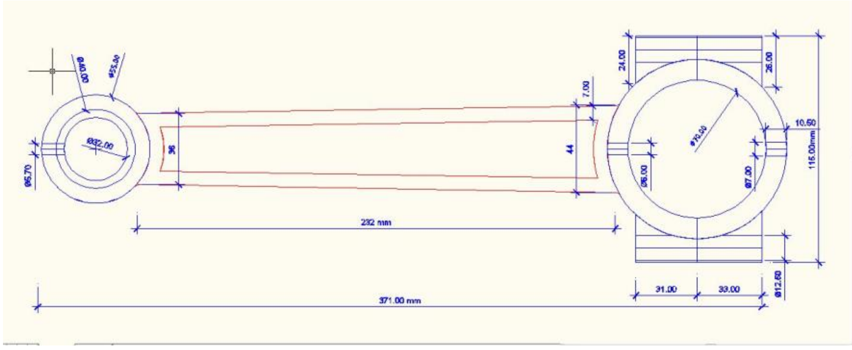

Figure 2: Sketch of the Sample-Connecting Rod

2.3 Determination of pattern dimensions

The following pattern allowances were considered during the development of the pattern size: linear shrinkage allowance; machining allowance and draft allowance.
Ibhadode (2001) provided the recommended values for a cast iron with the dimensions of the connecting rod as: linear shrinkage allowance = 0.01042 mm; machining allowance = 3 mm and draft allowance =1mm.
Hence, the dimensions of the connecting rod pattern and the connecting rod cap pattern were computed from the dimensions of the sample of connecting rod shown in Figure as follows:

2.3.1 Connecting Rod

1. Length of Pattern : 340 + 0.01042 + 3 + 1 = 344.01mm
2. Inner diameter of bearing shell: 70 + 0.01042 + 3 + 1 = 74.01mm
3. Outer diameter of bearing shell: 91 + 0.01042 + 3 + 1 = 95.01mm
4. Inner diameter of the short-arm: 40 + 0.01042 + 3 + 1 = 44.01mm
5. Outer diameter of the short-arm: 55 + 0.01042 + 3 + 1 = 59.01mm
6. Length of connecting rod shaft: 232 + 0.01042 + 3 + 1 = 236.01mm
7. Breadth of the long-arm of the connecting rod shaft: 44 + 0.01042 + 3 + 1 = 48.01mm
8. Breadth of the short-arm of the connecting rod shaft: 36 + 0.01042 + 3 + 1 = 40.01mm
9. Width of the long-arm of the connecting rod shaft: 35 + 0.01042 + 3 + 1 = 39.01mm
10. Width of the long-arm of the connecting rod shaft: 25 + 0.01042 + 3 + 1 = 29.01mm
11. Width of the of the connecting rod bearing shell: 54 + 0.01042 + 3 + 1 = 58.01mm
12. Width of the short-arm of the connecting rod : 48 + 0.01042 + 3 + 1 = 52.01mm
13. Length of the thread that attaches the cap to the connecting rod: 64 + 0.01042 + 3 + 1 = 68.01mm.
14. Diameter of the thread that attaches the cap to the connecting rod: 30 + 0.01042 + 3 + 1 = 34.01mm.

2.3.2 Connecting Rod Cap

1. Length of connecting rod cap: 47 + 0.01042 + 3 + 1 = 51.01mm
2. Breadth of connecting rod cap: 115 + 0.01042 + 3 + 1 = 119.01mm
3. Width of connecting rod cap: 54 + 0.01042 + 3 + 1 = 58.01mm

2.3.3 Sampled connecting rod parameters

1. Mass of the sample-connecting rod: 2.981 kg
2. Density of cast iron: 7.15 x 10^3 kg/m^3
3. Specific heat capacity of cast iron: 500 J/kg ^{o}C
4. Volume of sample-connecting rod: 4.17 x 10^{-4} m^3

2.4 Pattern fabrication

Two mould boxes were fabricated for the connecting rod pattern and the connecting rod cap pattern, as shown in Figures 3 and 4, respectively.

Figure 3: Pattern Mould Box for the Connecting Rod

Figure. 4: Pattern Mould Box for the Connecting Rod Cap

2.5 Design of the mould parameters

Mould parameters, such as diameter of riser; diameter of sprue; mould filling time and molten metal pouring velocity were computed as follows:

2.5.1 Design of Riser Size

According to Ravi (2003), the feeder compensates solidification shrinkage of the hot spot region. Hence, the volume of the feeder was computed as 5.36 x $10^{-5}$$m^3$ from eqn. (1):

$$V_f = \frac{\alpha V_c}{\eta_{f-\alpha V_c}} \tag{1}$$

where: V_c= volume of casting = 4.17 x $10^{-4}$$m^3$; η_f = efficiency of feeder (riser) = 0.14 and α = volumetric solidification shrinkage of cast metal = 0.018 (for cast iron)
The best shape of the riser for optimum run of casting is a cylindrical shape and the ratio of riser height to diameter usually varies from 1:1 to 3:2, Ravi [8]. Hence, the ratio of riser height to diameter used for the casting was eqn. (2):

$$\text{Riser height, } H = 1.5D \tag{2}$$

The diameter and the height of the cylindrical riser were computed as 0.0357m and 0.054m, respectively from eqns. (2) and (3):

$$D = \sqrt[3]{\frac{4\ V_f}{1.5\pi}} \tag{3}$$

2.5.2 Determination of mould filling time

The mould filling time was computed as 7.39sec from the generalized empirical equation for filling time [8], stated as eqn. (5):

$$\tau_t = Ko\left(\frac{K_f L_f}{1000}\right)\left[K_s + \left(\frac{K_t t}{20}\right)\right](K_w\ W)^p \tag{4}$$

where: K_o = overall coefficient = 1.0; K_f = coefficients for fluidity = 1.0; K_s = coefficients for size = 1.1; K_t = coefficients for thickness = 1.4 (for wall thickness up to 10 mm); L_f = fluidity length = 500 mm (for cast iron); K_w = coefficients for weight = 1.0; W = weight of casting = 29.21 N; t = section thickness = 39.01 mm and p = 0.4

2.5.3 Determination of pouring velocity

The liquid metal pouring velocity was computed as 1.05m/s from eqn. (5):

$$v = \sqrt{2gH_s} \tag{5}$$

where: H_s = mould metalostatic height (i.e. cope height + ½ ingate diameter) = 56mm and g = acceleration due to gravity = 9.81m/s^2.

2.5.4 Design of the sprue diameter

The sprue exit area and size (usually selected to control the pouring rate), were determined as 1.75 x 10^{-4}m^2 and 47.20mm, respectively from eqns. (6) and (7), as given by Ravi (2003):

The formula for finding the sprue choke area fn, is given as:

$$f_n = \frac{M}{\rho}\ \tau_f \mu v \tag{6}$$

where: ρ = molten metal density = 7.15 x 10^3 kg/m^3; v = liquid metal pouring velocity =1.05m/s; M = mass of casting in the mould (including risers, runners ingates and sprue well) = 2.981 kg and μ = discharge coefficient of the metal, usually $0 < \mu = 0.54 < 1$

$$d = 2\sqrt{\frac{f_n}{\pi}} \tag{7}$$

2.6 Production of patterns

The two patterns were produced: one wax pattern for the connecting rod and the other for the connecting rod cap as shown in Figure 5.

Figure 5: Pictorial view of wax pattern produced

2.7 Composition of the cast iron

The chemical composition of the cast iron by percentage weight (wt. %) is:
Carbon – 2.50; Silicon – 1.80; Manganese – 0.80; Sulfur – 0.15; Phosphorus – 0.15

2.8 Lost Wax Casting

The connecting rod was produced by reverse engineering of the original connecting rod, which was acquired from 8Hp diesel generator engine. A wax pattern was produced from the pattern mould that was made from ceramic material. The wax pattern was embedded into a green sand mould and heated to allow the wax to flow out of the mould thereby creating cavity of the shape of connecting rod. The same procedure was used to make the green sand mould of the connecting rod cap. Lost wax (investment casting) process was used to produce the connecting rod and its cap as shown in Figure 6, with pouring temperature in the range of 1430^{o}C (Kanno et al., 2006; Escobar et al., 2015). The produced pieces were machined to the dimensions of the original connecting rod and its cap.

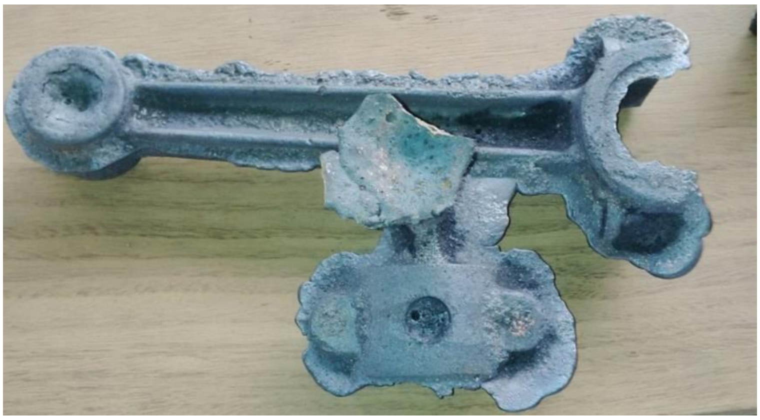

Figure 6: Connecting rod and cap produced by lost wax casting before machining

2.9 Connecting Rod Bushing

The connecting rod bushing which serves as a journal bearing inside the short arm of the connecting rod was produced by machining a cylindrical block into the required shape of a hollow ring. Bronze was selected as the material for this item because the original connecting rod had its bushing made of mild steel coated with bronze.

2.10 Inspection check of the produced connecting rod and cap

The dimensions of the cast connecting rod (prior to machining) were checked to see if its shrinkage values (mm/mm) were within the recommended range of values by the following analysis:

1. Full length of original connecting rod = 387 mm
   Full length of designed pattern of connecting rod = 395.02 mm
   Full length of cast connecting rod before machining = 392.21 mm
   Contraction of connecting rod = 2.81 mm
   True contraction (mm/mm) = 0.007 mm
2. Width of the original connecting rod cap = 54 mm
   Width of designed pattern of connecting rod cap = 58.01 mm
   Width of cast connecting rod cap before machining = 57.45 mm
   Contraction of connecting rod cap= 0.56 mm
   True contraction (mm/mm) = 0.0096 mm.

The computations of the true contractions of the full length and width of the connecting rod that was cast showed an approximate value of 0.01 mm each. This value is within the recommended shrinkage value of cast iron of this size, found in standard texts. This shows that the pattern that was produced is satisfactory.

2.11 Cast connecting rod parameters

1. Mass of the cast-connecting rod: 2.9892kg
2. Density of cast iron: 7.16×10^3 kg/m^3
3. Specific heat capacity of cast iron: 500 J/kg ^oC
4. Volume of sample-connecting rod: 4.18×10^{-4} m^3

2.12 Performance Tests

The connecting rod produced from this study (shown in Figure 7), was subjected to performance tests by interchanging it with the original connecting rod inside the diesel generator engine.

Figure 7: Connecting rod produced

2.12.1 Test for Engine Temperature

This test was carried out to measure the temperature rise of the diesel engine with respect to time using a digital read-out thermocouple. During this test the engine was run for duration of one hour under no-load and another one hour under a load of 3hp, and the engine temperature were recorded after an interval of 5 mins. First, engine temperature readings were taken when running the engine with the original connecting rod (i.e. control engine readings). Secondly, engine temperature readings were taken when the original connecting rod was interchanged for the reverse engineered connecting rod.

2.12.2 Engine Speed Test

The engine speeds were measured with a tachometer under the specified experimental conditions above and the readings were recorded. During this test the engine was run for duration of one hour under no-load and another one hour under a load of 3hp, and engine speed values were recorded after an interval of 5 mins.

3.0 RESULTS AND DISCUSSION

3.1 Results

3.1.1 Engine temperatures

The readings were taken for the control engine (i.e. engine with original connecting rod) and engine with produced connecting rod temperatures with respect to time as shown in Figure 8.

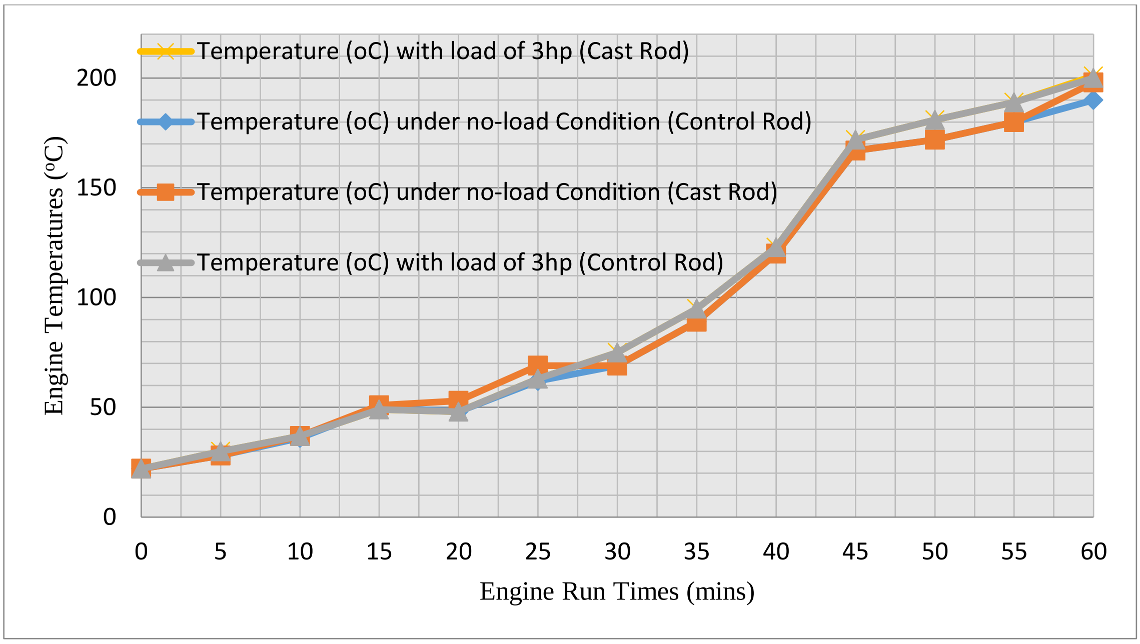

Figure 8: Engine temperature against engine runs time

3.1.2 Engine speeds

The speed of the engine was measured using the tachometer. Readings were taken for the control engine and engine with the manufactured connecting rod under the no-load condition and under a load of 3hp. This is shown in Table 1.

Table 1: Speeds of Control Engine

Operational condition	Control connecting rod	Produced connecting rod
	Engine speed (rpm)	Engine speed (rpm)
Under No-load Condition	850	793
Under a load of 3hp	824	786

3.2 Discussion

Figure 8 shows the plot of engine temperatures against run times, under the no-load condition and under a load of 3 Hp for the control connecting rod and the cast connecting rod. The figure shows that there was a steady rise in temperature under the no-load condition and under a load of 3 Hp for the first 15 mins of running the engine. After 20 mins of running the engine, the temperature dipped with 2°C under the no-load condition and 1°C under a load of 3hp for the control connecting rod as well as the cast connecting rod. The engine temperature began to rise again after 25 mins under both experimental conditions. However, both experimental conditions recorded the highest temperature difference at 45 mins, with the engine under no-load condition recording an increase of 47^{o}C and the engine under a load of 3hp recording a temperature rise of 49^{o}C within the same space of 5 mins. Again, the result showed that after 1 hour of running the control engine, the engine under a load of 3hp recorded the highest temperature of 200^{o}C while the engine under no-load condition recorded a temperature of 190^{o}C. This figure showed a curve with sharp increase in temperature from 20 mins to 50 mins. The temperature curve became mildly slant between 50 mins and the 1 hour mark, indicating a closer temperature difference at that range of time. For the cast connecting rod the engine temperature did not dip under a no-load condition but dipped with 1^{o}C under a load of 3hp at 20 mins. However, the engine under no-load condition recoded its lowest temperature rise of 2^{o}C at 20 mins. Again, under the no-load condition, there was 0^{o}C temperature rise between 25 mins and 30 mins as the temperature was stable at 69^{o}C. The engine under load of 3hp recorded the highest temperature of 201^{o}C after I hour while the engine under no-load condition recorded a temperature of 198^{o}C. This figure showed that the engine under load of 3hp had the steepest slope when compared with engine under no-load. Table 1showed the values of the engine speeds under the two experimental conditions for the control engine. From the table, the engine speed reduced with 3.06% under 3hp load condition as against the value of 250 rpm when the control engine was under no-load condition. Table 1 also shows the same decrease in value for the engine with the manufactured connecting rod. The speed of the engine reduced with 0.88% under 3hp load condition from the 793 rpm recorded under no-load condition. However, the reduction in speed was more for control engine than for engine with the manufactured piston.

4.0 CONCLUSION

The values obtained for engine speeds and engine temperatures for the control engine and the engine with the manufactured connecting rod were very close under the two experimental conditions, which confirmed that the efficiency of the manufactured connecting rod is close to that of the original connecting rod.

5.0 REFERENCES

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